Chapter-5 (upthrust in fluids and floatation)

1. Upthrust and Archimedes Principle

Have you ever wondered why there is some resistance when you try to push an object inside water? Have you tried to find out why do you find it difficult to push that object further into the water? Read on to get an answer.

Whenever you try to push an object inside water, it exerts an upward force or an upthrust which is nothing but the buoyant force. It is due to this buoyant force that you will feel lighter when you are inside a swimming pool.

Archimedes' principle is explained based on this upthrust. In this topic, you will learn more about upthrust in fluids and Archimedes' principle.

Characteristic properties of Upthrust and Definition of Upthrust

1. When a body is partially or wholly immersed in a liquid, an upward force acts on it.

2. This upward force is known as upthrust or buoyant force.

3. It is denoted by the symbol FB .

4. Its unit is newton (N) or kgf.

Definition of Buoyancy

1. The property of a liquid to exert an upward force on a body immersed in it is called buoyancy.

For example, while pushing a cork into water, our fingers experience the net upward force.

2. Like liquids, gases also have the property of buoyancy i.e. a body immersed in a gas also experiences an upthrust.

For example, a balloon filled with hydrogen rises up because of upthrust.

Condition for a body to float or sink in fluid

1. If FB > W or FB = W, the body will float.

2. If FB < W, the body will sink.

3. FB = upthrust or buoyant force acting vertically upwards.

4. W = weight of the body acting vertically downwards.

How will the body float

1. For FB > W

2. The body will float with only that much part (partly immersed) of it inside the liquid, the upthrust due to which becomes equal to the weight of the body.

3. For FB = W

4. The body will float with the whole of it immersed inside the fluid.

5. For a floating body, the net force acting downwards (i.e. apparent weight) is zero.

Effect of Upthrust

The effect of upthrust is that the weight of the body immersed in a liquid appears to be less than its actual weight.

1. Larger the volume of the body submerged in fluid, greater is the upthrust.

2. More the density of the fluid, greater is the upthrust.

3.The upthrust acts on a body in an upward direction at the centre of gravity of the displaced fluid which is called the centre of buoyancy.

Factors affecting the Upthrust

1.The magnitude of upthrust on a body due to a liquid depends on:.

2. volume of the body submerged in the liquid (or fluid).

3. Density of the liquid (or fluid) in which the body is submerged.

4. Magnitude of upthrust = FB = Volume of body submerged in liquid × density of liquid.

Mathematical Proof

Upthrust is equal to the weight of the liquid displaced.

1. Consider a solid cylinder of height 'h' and area of cross-section A, to be completely immersed in a fluid of constant density p.

2. FB = $h_2$pgA – $h_1$pgA = A(h_2 – h_1)pg = Vpg.

3. V is the volume of cylinder submerged in liquid.

4. Upthrust = weight of the liquid displace.

5.The bodies of average density greater than that of liquid, sink in it.

The bodies of average density equal to or smaller than that of liquid, float in it.

Archimedes' Principle

Archimedes' principle states that when a body is immersed partially or completely in a liquid, it experiences an upthrust, which is equal to the weight of the liquid displaced by it.

Relative Density and its Measurement by Archimedes Principle

Density:

The density of a substance is its mass per unit volume.

Density (p) = Mass (M) / Volume (V)

S.I. unit of density is kg m^{-3}

Relative Density:

Relative density (R.D.) of a substance is the ratio of the density of the substance to the density of water at 4°C.

It is also defined as the ratio of the mass of the substance to the mass of an equal volume of water at 4°C.

R.D. has no unit.

R.D. of a solid substance by Archimedes' principle:

R. D. = Weight of the body in air / (Weight of the body in the air – Weight of the body in the water)

R.D. of a solid substance soluble in water:

If the solid is soluble in water, we take a liquid instead of water, in which the solid is insoluble and the solid sinks in that liquid.

R.D. =Weight of the solid in air / (Weight of the body in the air – Weight of the body in the water)

Hydrometer:

A hydrometer is an instrument, which is used for measuring the relative density of a liquid (heavier or lighter than water) directly and hence to test the purity of a liquid.

A hydrometer is usually made of glass, and consists of a cylindrical stem and a bulb weighted with mercury or lead shot to make it float upright. The liquid to test is poured into a tall container, often a graduated cylinder, and the hydrometer is gently lowered into the liquid until it floats freely. The point at which the surface of the liquid touches the stem of the hydrometer correlates to specific gravity. Hydrometers usually contain a scale inside the stem, so that the person using it can read specific gravity.

While floating, the length of the hydrometer immersed in a liquid is inversely proportional to the density of the liquid in which it is placed

l α 1/p

R.D. of a liquid = Density of liquid / Density of water

R.D. of a liquid =Length immersed in water / Length immersed in liquid

Lactometer:

It is a specially designed hydrometer which is used for measuring the relative density of milk and hence testing the purity of milk.

The specific gravity of milk does not give a conclusive indication of its composition since milk contains a variety of substances that are either heavier or lighter than water. Additional tests for fat content are necessary to determine overall composition. The instrument is graduated into a hundred parts. Milk is poured in and allowed to stand until the cream has formed, then the depth of the cream deposit in degrees determines the quality of the milk.

Acid Battery Hydrometer:

A hydrometer used to check the concentration (or the relative density) of sulphuric acid in an acid battery is called the acid battery hydrometer.

. Floatation

Floatation:

When a body is in fluid there are two forces acting on it.

1.A force equal to its weight, acting downwards.

2.Buoyant force, acting upwards.

According to the principle of flotation, the weight of a floating body is equal to the weight of the liquid displaced by its submerged part.

When a body is immersed partly or completely in a liquid it is under the influence of two forces,

1. The weight of the body W, body acting vertically downwards, through the centre of gravity G of the body.

2. The upthrust or buoyant force FB, acting upwards on the body.

W = Vpsg = (total volume of the body x density of the body x g)

The upthrust FB of the liquid acting vertically upwards, through the centre of gravity of the displaced liquid, called the centre of buoyancy B

FB = Vsplg (Volume of submerged part of body x density of liquid x g)

Note that FB = the weight of liquid displaced by the body

Depending on the values of weight of the body W and buoyant force FB, there are 3 possibilities:

1. W > FB implies that the body will sink
2. W = FB implies that the body will float just inside the surface of the liquid
3. W < FB implies that the body moves to the surface and floats on the surface of the liquid.

Principle of Floatation:

According to the principle of floatation, the weight of a floating body is equal to the weight of the liquid displaced by its submerged part.

Apparent weight of a Floating Body:

Apparent weight = True weight – Upthrust = W – FB = 0

Thus a floating body appears to have no weight or its apparent weight is zero

The mathematical relation for a Floating Body:

W = Vpsg = FB = Vsplg

Vps = Vsplg $\Rightarrow$ Vs/V = ps/(pl)

Volume of submerged part of bodytotal volume of body

Applications of the Principle of Floatation:

1. Floatation of iron ship

2. Floatation of man

3. Floatation of submarine

4. Floatation of iceberg

5. Rising of balloons

6. Floatation of fish